Representation of Fronts in Global Atmospheric Models

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The overall objective of this project is to develop diagnostic methodologies for exposing the kinematics and dynamics of the life cycles of extratropical cyclones, with particular emphasis on representing the structure of fronts and jets, as portrayed in global analyses and simulated in general circulation models (GCMs). This effort is being performed in support of the research activities of the Impact Group of the Satellite Data Utilization Office at the NASA/Goddard Space Flight Center in the areas of the dynamics of atmospheric phenomena and observing system simulation experiments (OSSEs). The principal investigator's role is advisory: computations and data analyses are performed in the Impact Group of the Satellite Data Utilization Office under the direction of Dr. Robert M. Atlas and carried out on a day-to-day basis by Dr. Juan Carlos Jusem and support staff.

Although fronts and jets are not particularly well resolved in contemporary GCMs, it is anticipated that advances in computational and remote-sensing observing technologies will allow future GCMs to possess horizontal and vertical resolution comparable to that of present-day regional-scale models. With the removal of the need for artificial lateral boundary conditions, GCMs that explicitly resolve mesoscale circulation systems will open up the opportunity to perform comprehensive studies of the life cycles of cyclones and fronts, along with the interactions of these features with the larger-scale wave regimes in which they evolve. The implementation of the diagnostic methodologies proposed in this project in advance of the routine availability of mesoscale-resolution GCMs is believed to constitute a prudent investment in "research infrastructure": the payoff of this investment is expected to take the form of a well-established capability to utilize progressively higher-resolution versions of GCMs for performing diagnostic case studies, as soon as such models become available.

Efforts during this past year have focused on representing and diagnosing divergent vertical circulations in the vicinity of fronts and jets. Toward this end, Dr. Jusem, in collaboration with the principal investigator, has adapted the so-called "psi-vector methodology" (Keyser et al. 1989; Loughe 1992) to apply

to spherical-coordinate geometry on a global domain. An attractive attribute of this approach is that it permits the directional partitioning of divergent circulations in arbitrarily oriented orthogonal vertical planes. The extension to a global domain is noteworthy because it allows the unique partition between the rotational (i.e., nondivergent) and divergent (i.e., irrotational) flow, which is not readily achieved on a regional domain. Although the psi-vector methodology has been applied so far only to jet/front systems, it is not scale-dependent, so that it may be applicable to any atmospheric circulation system in which there are preferred directions to the vertical circulation (e.g., cross- and along-front: fronts and jets; zonal and meridional: Walker/Hadley circulations). Although the adaptation in progress is not sufficiently general to include orography, the principal investigator has derived a sigma-coordinate counterpart of the present pressure-coordinate version. Such a generalization may be considered as part of the research effort to be undertaken during the next year.

The remainder of the research effort during this past year involves illustration of the spherical-coordinate psi-vector technique through a reexamination of the cold-air injection phenomenon (George 1960; Atlas et al. 1980) from a vertical-circulation perspective. A case is examined for the period between 12-14 January 1979, when a well-defined northerly low-level jet develops along the eastern slopes of the Rockies. A finding of considerable interest is that the low-level jet may have been initiated, in part, by a troposphere-deep direct vertical circulation associated with upper-tropospheric confluence. The significance of this finding is that it runs counter to "conventional wisdom," which envisions the formation and evolution of such jets to be a low-level process completely controlled by orography. The results to date of this study are summarized in the preprint entitled, "Evolution of a Low-Level Jet in Relation to an Upper-Level Baroclinic Disturbance East of the Rocky Mountains," by R. M. Atlas, J. C. Jusem, and D. Keyser, to be presented by Dr. Jusem at the Symposium on the Life Cycles of Extratropical Cyclones, to be held 27 June - 1 July 1994, in Bergen, Norway. We plan to adapt this preprint toward publishable form within the next year; this adaptation requires documenting the spherical-coordinate version of the psi-vector technique and illustrating this technique with the above-described case study of low-level jet formation.

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